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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 890

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C.

Issued October 7, 1920
Revised April, 1925

# MILK-PLANT EQUIPMENT

By

ERNEST KELLY, in Charge of Market Milk Investigations, and
CLARENCE E. CLEMENT, Market Milk Specialist, Bureau of Dairying

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## SELECTION OF EQUIPMENT.

Great care must be given to the selection of milk-plant equipment. Many mistakes have been made through the selection of too much machinery or machinery which was too complicated. In other cases it has often been found after the equipment has been put in operation that the capacity of different machines was either too great or too small. Such mistakes in selecting equipment are usually detected when it is too late, and it would be advisable, therefore, to consider seriously the following points before buying the equipment for a milk plant:

1. *Simplicity.*—The simpler the machine the better. Unnecessary parts make the machine difficult to operate and to clean and more liable to get out of order.

2. *Ease of cleaning.*—Unless the machine can be cleaned easily the labor of cleaning will be greater, and the work may be neglected. There should be a minimum of parts and joints not easily accessible.

3. *Ease of sterilizing.*—Some types of machinery are much easier to get at for steaming than others. All apparatus in which milk is handled must be sterilized daily with live steam; hence the item of "inaccessibility" should not be overlooked.

4. *Initial cost.*—Machinery should not be purchased on the basis of cheapness alone; it is often economy to purchase some of the highest-priced machines. The initial cost, however, must be considered and weighed against all other factors.

5. *Rapidity, ease, and economy of operation.*—A study of the machinery in actual operation is necessary to determine these factors.

6. *Avoidance of rubber gaskets and fittings.*—All fittings in milk-handling equipment, so far as possible, should be of metal.

7. *Proper capacity.*—The equipment purchased should be of sufficient size to handle all probable increase of business; but it should be borne in mind that plant equipment depreciates rapidly, and it is not advisable to procure oversize apparatus which will not last until the anticipated increase has taken place.

8. *Durability.*—Cheap machinery often wears out or gets out of order in a very short time. It is more economical to purchase a well-constructed and durable machine even if the initial cost is somewhat higher.

The life of milk-plant equipment and machinery will depend upon the original condition, amount of use, and the care given it. As a rule such equipment receives hard and constant usage and depreciates quite rapidly. The average annual depreciation of all milk-plant equipment in 69 plants varied from 4 to 33½ per cent, with an average of 14.6 per cent. The annual per cent of depreciation of the various items of equipment in 20 other plants was as follows:

TABLE 1.—*Depreciation of various items of equipment in 20 plants.*

| Type of machinery. | Annual depreciation. | Variation. |
|---|---|---|
| | *Per cent.* | *Per cent.* |
| Bottle fillers and cappers | 18.2 | 10–30 |
| Bottle washers | 17.2 | 10–20 |
| Pasteurizers | 18.8 | 10–30 |
| Power-plant equipment | 9.4 | 5–15 |
| Cans | 20.0 | 15–30 |

At 12 of these 20 plants the depreciation was 20 per cent on fillers and cappers, bottle washers, and pasteurizers, while at 8 of them the depreciation on power-plant equipment was 10 per cent, these figures being the most common.

It may be safely estimated that at the average plant the milk-handling equipment depreciates nearly 20 per cent, or, in other

words, its average life is about five years. At many plants the life of the equipment is much longer, however, often exceeding 10 years, due largely to better machinery and to the good care that it receives. The low average life in a great measure is due to the fact that after a few years the machinery becomes obsolete and has to give way to modern equipment. In the case of cans these figures do not necessarily indicate that a can will wear out in five years; much of the depreciation is due to lost cans.

## EQUIPMENT REQUIRED.

In general, the following equipment is required for the ordinary city milk plant:

1. Weigh can, with platform scales.
2. Drip saver.
3. Receiving vat or jacketed, glass-lined storage tanks.
4. Clarifier or filter.
5. Pasteurizer.
6. Holder.
7. Cooler.
8. Temperature regulators and recorders.
9. Supply tank to the filler.
10. Fillers and cappers.
11. Bottle washer.

FIG. 1.—Dump or weigh can with platform scales. Tank sunk in floor to make dumping of milk easier.

12. Can washer.
13. Labor-saving devices, as elevators and conveyers.
14. Boilers, engines, refrigeration machinery, motors, hot-water heater, etc.
15. Sanitary milk pumps and piping.
16. Separator and churn.
17. Cans, bottles, cases, etc.

## SCALES AND WEIGH CAN.

At very small plants the milk can be weighed in the cans and the weigh tanks will not be needed. In all cases, whether milk is paid for by the gallon or by weight, it should be weighed. If milk is paid for by the gallon the weight can be readily converted to gallons; in fact, there are scales on the market which record the quantity in gallons as well as pounds. One company handling a little more than 4,000 gallons of milk daily decided after several years to buy and sell the milk by weight. Scales were installed and the difference between the measure by the cans and the actual quantity of milk received, as shown by the scales, was determined. Table 2 shows the differences in a two-month test.

TABLE 2.—*Difference between can measure and actual quantity of milk received as shown by scales, at a city plant.*

| Items. | First month. | Second month. |
|---|---|---|
| | *Gallons.* | *Gallons.* |
| Can measure | 126,460 | 138,485 |
| Scale | 124,331 | 135,941 |
| Difference | 2,128 | 2,544 |

Thus, during April there was a difference of 2,128 gallons and in May 2,544 gallons. At this rate the plant paid for over 2,000 gallons of milk more than it actually received in each of the two months, or a difference of more than $600 a month, if milk is worth 30 cents a gallon.

At another plant, where the milk was received by measure, 55 10-gallon cans of milk were weighed, first weighing the full can and then weighing the empty can after it had drained on a drip pan. The lowest net weight for the can of milk was 80 pounds and the highest 85¾ pounds, or a variation of 5¾ pounds. The average of the 55 cans was 83¾ pounds, or 2¼ pounds less than the usually accepted weight for 10 gallons of milk. Only full cans were included, so the dealer actually lost 3.19 per cent. This dealer handled 2,000 gallons daily, and valuing the milk at 30 cents a gallon the daily discrepancy would be 63.8 gallons, or an overpayment of $19.14. The purchase

of a set of scales would provide for an equitable method of purchasing milk, whereby farmers would receive full payment for the exact quantity of milk delivered.

Losses of milk which result from buying by measure instead of by weight are due to the following causes:

1. Cans not filled by farmer.
2. Milk slopped in transit.
3. Cans dented and not holding full quantity.
4. Leaky cans.
5. Loss from contraction and expansion of milk. (Experiments have shown that milk shrinks at least 0.2 per cent in cooling from 70° to 50° F.)

## DRIP SAVER.

A drip saver (fig. 2) helps to reduce the loss from shrinkage of milk. This may be a homemade affair or one can be purchased at a moderate price from a dairy-supply company.

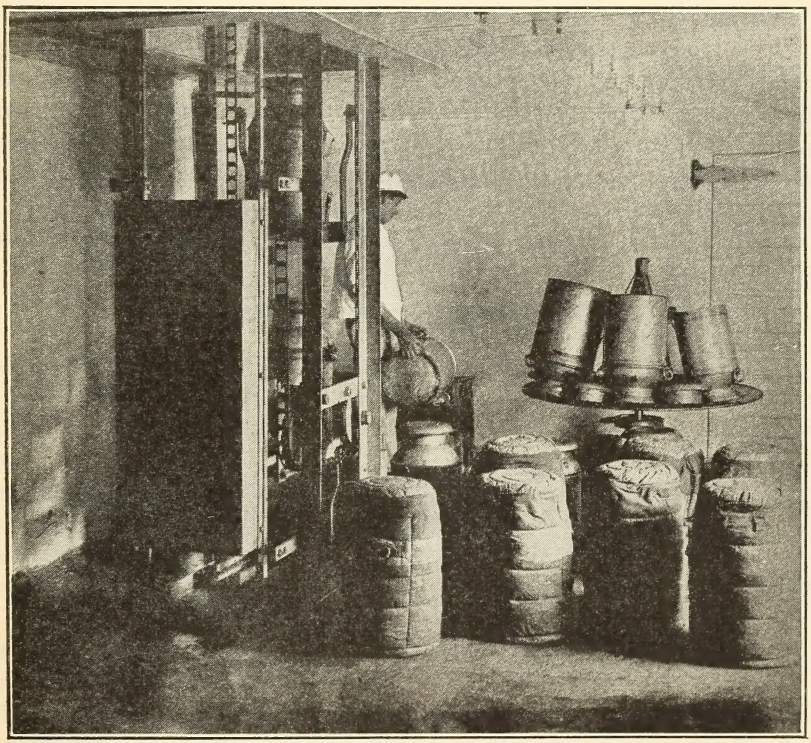

FIG. 2.—Method of draining cans to prevent waste. The illustration shows also jacketing of cans to keep milk cool.

The following table shows the quantities of milk saved by drip savers at several plants:

TABLE 3.—*Quantity of milk saved by drip savers at several plants.*

| Plant No. | Quantity of milk dumped. | Milk saved with a drip saver. | |
|---|---|---|---|
| | *Gallons.* | *Gallons.* | *Per cent.* |
| 1 | 6,000 | 16 | 0.266 |
| 2 | 4,000 | 15 | .375 |
| 3 | 3,000 | 12 | .40 |
| 4 | 2,000 | 6 | .30 |

Losses of milk from handling in city milk plants as reported by 115 dealers varied from 0.3 per cent to 7 per cent, and the average was 2.29 per cent. If a dealer handles 3,000 gallons daily, with a shrinkage of 2.29 per cent, his daily loss would be 68.7 gallons, or at 30 cents a gallon, $20.61, or $7,522.65 a year. Such a loss is a big item and every precaution should be taken to keep down the shrinkage.

There is necessarily a certain amount of shrinkage in transferring milk from cans to bottles and in the process of clarifying and pasteurizing. Special attention to this matter, however, has been given by some plants and the losses considerably reduced. Collecting pans should be placed under all milk apparatus where milk is apt to spill, and especially under the filling machines, to catch all drip. While the milk saved should not go back to the filler, it may be utilized in other ways.

## RECEIVING VAT AND STORAGE TANKS.

Jacketed storage tanks or a receiving vat are used to hold the milk from the time it is received and dumped until it goes to the pasteurizer. The storage tanks are insulated and are often fitted with jackets so that the milk can be kept cold by means of brine. (See fig. 3.) The milk is agitated by air blown in from the bottom or by a revolving paddle. These tanks are valuable where milk is to be held for a considerable time before it is pasteurized. At many plants milk is held in these tanks for several hours and a great saving in milk cans, refrigeration, labor, and floor space is effected.

If the milk is not held over for any considerable time it can be held in an ordinary receiving vat which may have revolving coils containing the cooling medium that keeps the milk cool and agitated. A larger receiving vat will be required if the continuous system of pasteurization is used than if the vat system is employed, as in the latter case the milk may go direct to the pasteurizing vats.

## CLARIFIER.

The clarifier (fig. 4) is a centrifugal machine used to remove visible dirt from the milk. There are on the market several clarifiers that do very efficient work.

## PASTEURIZATION.

Pasteurization is quite generally recognized as necessary unless milk has been produced and handled under special conditions that make its use safe in the raw state. The proper pasteurization of milk consists in heating it to 145° F., and holding it at that temperature for 30 minutes. All disease-producing bacteria which may occur in milk are destroyed by proper pasteurization, and a considerable quantity of other bacteria are also destroyed, so that, provided the milk is properly taken care of after pasteurization, its keeping quality will be improved.[1]

Formerly milk was pasteurized to a large extent by the "flash" system. By this system the milk is heated to 155° F. or higher and then cooled. Exhaustive laboratory investigations, as well as actual

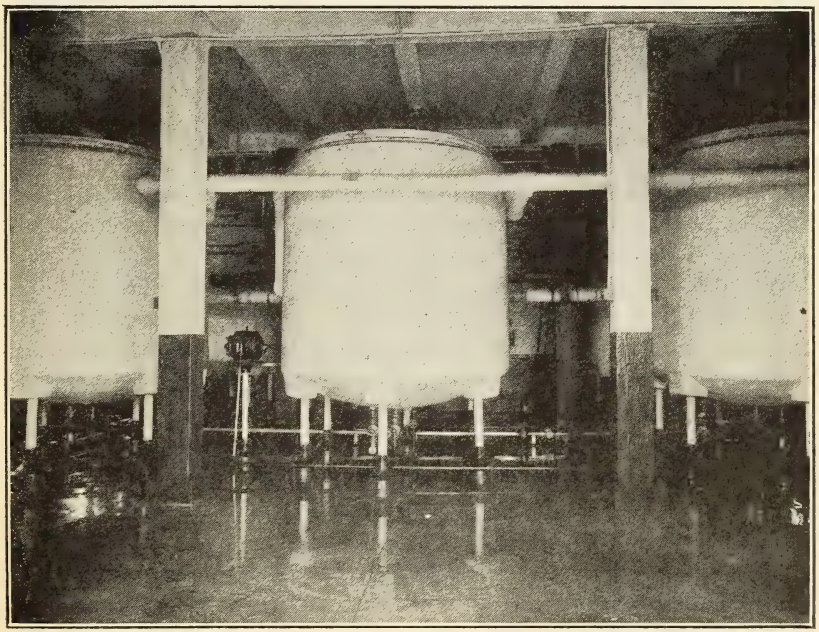

FIG. 3.—Milk-storage tanks used in large plants to store milk at low temperature before it is pasteurized.

practice on a commercial scale, have shown that this system is not satisfactory, and that positive holding is necessary.

[1] For detailed information on pasteurization see Bureau of Animal Industry Circular 184, Bureau of Animal Industry Bulletin 161, and Department Bulletin 342.

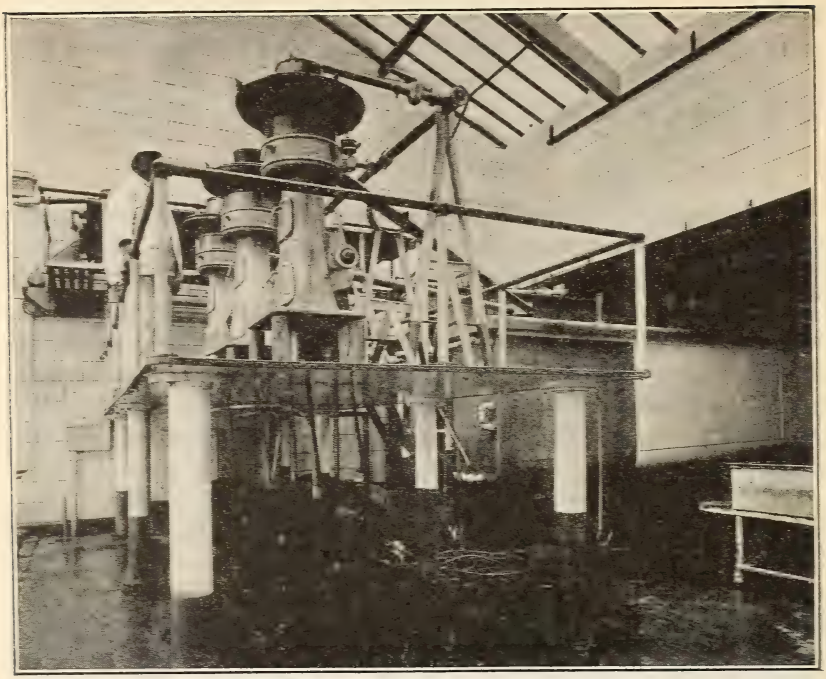

FIG. 4.—Battery of clarifiers used at a large plant.

## SELECTION OF PASTEURIZING EQUIPMENT.

A large number of different types and styles of pasteurizers are on the market, and one should know what requirements are to be fulfilled before attempting to select a machine.

In general the type of pasteurizer selected should be adapted to the particular plant for which it is intended. A small plant will often require a different type of machine from a large one. A plant handling milk only may require a type different from that required by one handling by-products also.

Other questions which have a bearing on the selection of a pasteurizer are: Is the daily output constant? Is the business increasing or constant? The large dealer must have a machine that will handle a large volume of milk in a short time.

Among the points to be considered in the selection of a pasteurizer are the following:

1. Simplicity of the machine.
2. Ease of cleaning.
3. Ease of sterilizing.
4. Economy of operation.
5. Avoidance of high temperatures in the heating medium by having a large heating area.
6. Accuracy of holding.

7. Initial cost.
8. Durability.
9. Avoidance of chance of forcing the milk through at too high a speed.
10. Ease and rapidity of operation.
11. Elimination of milk pumps, whenever practicable.
12. Adaptability to increased capacity, by installing additional units.
13. Minimum of unnecessary agitation of milk.
14. Floor space required.
15. Minimizing human element in operation.
16. Heating all of the milk uniformly.

A pasteurizer with parts not easily accessible will require extra time to keep it clean and should be avoided. It is important that the pasteurizer have a large heating area, so that the temperature of the heating medium need not be much higher than the temperature to which the milk is to be heated. This will avoid the danger of heating some parts of the milk to too high a temperature, which gives it a scorched or burned taste and may also injure the cream line.

To be on the safe side the temperature of the heating medium should not be more than 10° or 15° F. above that to which the milk is to be heated. As a heating medium water gives good results and its temperature should be under control at all times. Steam should not be used direct as a heating medium in most types of pasteurizers.

By applying the so-called "regenerative" principle to the heating and cooling media many plants are able to cut down the amount of heat and refrigeration required. This principle may be applied by either the "milk regenerative" or the "water regenerative" system. With the milk regenerative system the cold milk coming into the pasteurizer passes through the first section of the cooling tubes over which the hot milk from the holder flows. In this way the incoming milk is partly heated, often to between 110° and 120° F. before it goes to the heater proper, while the milk going over the cooler is cooled by the incoming milk inside the tubes to 60° or 70° F. before it reaches the tubes containing the cooling water.

With the water regenerative system the water from the first section of the cooler, having been heated to within a few degrees of the hot milk, needs to have only a few heat units added to it before it goes to the heater to heat the incoming milk. The water from the heater in turn having been cooled by the incoming milk goes to the cooler, where it is used for cooling the hot milk. The water regenerative system is the most desirable, as much cleaning of milk pipes is necessary with the milk regenerative system. Temperatures obtained with regenerative systems of pasteurizing are shown in Table 4.

At many plants the milk is preheated by means of this regenerative principle to about 85° or 90° F. before it goes to the clarifier. At that temperature clarification is more efficient and less foam is pro-

duced. Preheating also renders the pasteurization more nearly uniform, as the milk goes to the machine at a fairly constant temperature.

TABLE 4.—*Temperatures of milk at pasteurizing plants that use regenerative systems.*

| Plant No. | Temperature of milk as received. | Temperature after preheating by regenerator, before going to heater. | Degrees heated by hot milk. | Temperature of milk coming from holder. | Temperature after precooling by regenerator, before going to cooler. | Degrees cooled by cold raw milk. |
|---|---|---|---|---|---|---|
| | ° F. | ° F. | ° F. | ° F. | ° F. | ° F. |
| 1 | 40 | 120 | 80 | 144 | 50 | 94 |
| 2 | 36 | 116 | 80 | 144 | 61 | 83 |
| 3 | 34 | 114 | 80 | 145 | 52 | 93 |
| 4 | 40 | 120 | 80 | 145 | 60 | 85 |
| 5 | 39 | 116 | 77 | 141 | 66 | 75 |
| 6 | 45 | 120 | 75 | 144 | 60 | 84 |
| 7 | 40 | 110 | 70 | 144 | 65 | 79 |
| 8 | 42 | 108 | 66 | 142 | 66 | 76 |
| 9 | 40 | 65 | 25 | 145 | 60 | 85 |
| Average | 39 | 109 | 70 | 144 | 60 | 84 |

NOTE.—The milk regenerative system described in a previous paragraph was used in these plants.

For a complete system of proper pasteurization the following equipment must be obtained:

1. Heater.
2. Holder.
3. Cooler.

In some cases the same apparatus may be used for all three processes.

### HEATERS.

In general, there are two types of heaters, the batch system heater and the continuous-flow heater.

#### BATCH HEATERS.

In the batch system the milk is heated in a vat, on the inside of which is a coil through which the heating medium, usually hot water, is forced. This coil revolves slowly and gently agitates the milk. The hot water is either pumped through the coil or forced through by air and by the revolving of the coil.

Some of the older types of vats are provided with disks instead of coils, but they are much less satisfactory and are more likely to get out of order. It takes from 15 to 30 minutes to heat the milk in the vat, and after it has reached the desired temperature (145° F.) it is held in the same vat for 30 minutes. The vat should be well insulated to prevent loss of heat during the holding process. The coils are sometimes allowed to revolve during the holding process so that the cream will not rise and the milk will be held at a more uniform temperature.

One of the dangers of the vat system is that the milk may be started out of the vat before it has been held for 30 minutes. At one plant it was noted that the milk was started out of the vat 11 minutes after it was brought up to 145° F. It was then allowed to go over a tubular cooler. The cooling process took about 35 minutes, so that while the last of the milk was held for 45 minutes the first part was held for only 11 minutes.

Other types of batch heaters consist of jacketed tanks, often glass lined, or of vats in which the milk is agitated by a mechanical contrivance. Heat is supplied by steam or hot water in the outer jacket.

Milk may be cooled in the vat by forcing cold water and brine through the coils, or by water jackets, or it may be run over a separate cooler. Where it is cooled in the vat the process is very slow, and the milk will not show a clear cream line so readily as when cooled quickly over a separate cooler. Cooling in the vat also may cause leaks in the coils, due to the repeated sudden changes in temperature. A continuous system may be obtained with the batch system of pasteurization by using a battery of three or more vats. While the third vat is being filled and heated the milk in the second vat is being held and that in the first vat is being drawn off to the cooler. The time required to empty the vat depends somewhat on the capacity of the cooler, so it is important that the cooler be of ample capacity. The capacity of the vats may be increased by preheating the milk by some form of heater before it enters the vats. If the milk is slightly cooled in the vats before it is allowed to go to the cooler the time the milk is held at 145° F. will be made uniform for all the milk

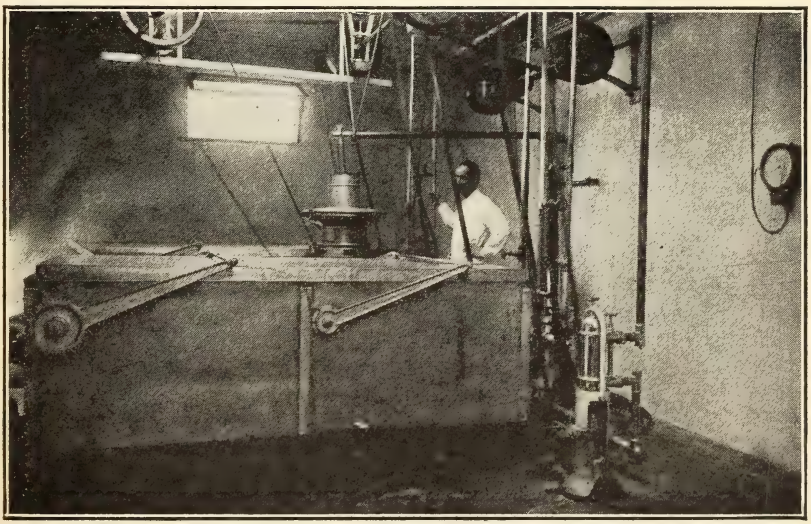

FIG. 5.—Pasteurizing milk by the batch or vat system.

and the capacity of the outfit will be increased. Another advantage of precooling is that the records will show the exact time the milk was held at 145° F. if a recording thermometer is used.

The covers of this type of heater should be kept closed; otherwise there may be a considerable loss from evaporation and the milk may be contaminated. It is important with the vat system that the coils revolve at the proper speed. If they are allowed to run too fast the milk will be unduly agitated and injury to the cream line may result. The ordinary 300-gallon vat should be run at 45 revolutions a minute.

Some of the advantages of vat heaters are:

1. Simplicity. The apparatus is very simple.
2. Easily operated.
3. The vats are durable and comparatively inexpensive. One vat may serve for heating, holding, and cooling, though the last is not usually advisable, as previously mentioned.
4. For small plants the vats are economical, on account of the many uses to which they may be put. Besides serving as heater, holder, and cooler, the vat also may serve as a dump tank and storage tank for the milk. The milk may be placed in the vat when received and be held in the vat at the desired temperature until ready for pasteurization. Where a wholesale business is conducted, the milk may be held in the vats at low temperature after it is pasteurized and cooled until the cans are filled and sent out to the wholesale trade.
5. The time of holding can be positive if operated properly.
6. During the holding process the milk comes into contact with no new surfaces between the completion of the heating process and the time the milk is cooled; thus there is less chance for contamination and less apparatus to clean.
7. The capacity of the plant may be readily increased by adding another unit. (A small plant may get along with one vat for a while, and as the business increases additional vats may be added and a continuous system established.)

Some of the disadvantages of the vat system are:

1. Some operators have difficulty in obtaining a good cream line with this system.
2. A comparatively long time is required to heat the milk.
3. It is not automatic. The attendant must spend a considerable portion of his time operating the valves for filling and emptying the vats.
4. With some types of vats the bearings or stuffing boxes of the coils, unless properly taken care of, may come into contact with the milk, and leaks may cause considerable trouble.
5. All milk is not held at the pasteurizing temperature the same length of time. Some of the milk may be held more than 30 minutes, and thus the cream line may not be so clear. If the milk is precooled a few degrees in the vat before going to the cooler this disadvantage may be eliminated.

### CONTINUOUS-FLOW HEATERS.

The most common continuous-flow heaters may in general be classified into three types, which have sometimes been designated as

the "kettle" or "Danish" heater, the "drum" or "film" heater, and the "internal tubular" heater.

*Kettle or Danish heater.*—The kettle or Danish heater (fig. 6) consists of a kettlelike receptacle in which the milk is heated by a water jacket surrounding it. Into this jacket steam is introduced in order to bring the contents to the desired temperature. The milk enters the inside of the apparatus at a point near the bottom and is forced out at the top by means of revolving paddles. These paddles may force the milk upward for 5 to 10 feet, and thus the machine acts as a pump. The heating surface is comparatively small, and it is therefore necessary to use a high temperature in the heating medium. For this reason it is very difficult to get a uniform temperature for all portions of milk going through this heater.

This type of heater is often used where milk is heated and not held for any length of time; but it may also be used with nearly any type of holder. The system of heating milk to high temperatures for short periods is known as the "flash" process of pasteurization. This system is not desirable, but the heating units are satisfactory if used in connection with a holding device.

The principal advantages of this type of heater are:

1. Inexpensiveness.
2. Small floor space required.
3. It is economical and easy to operate.
4. It is quite easily cleaned.
5. It may act as a pump to elevate the milk to the holder.

The principal disadvantage of this type of heater is the difficulty of maintaining a uniform temperature. The area of the heating

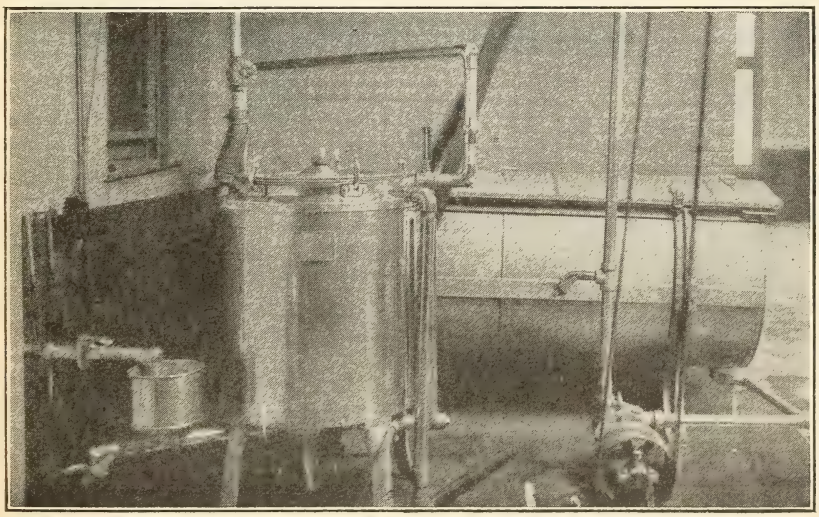

FIG. 6.—Pasteurizer or the Danish or "kettle" type, with retarder.

surface is so small that the heating medium must be of a considerably higher temperature than that to which the milk is to be heated, and steam is introduced directly into the heating chamber. As the heating medium is sometimes allowed to run as high as from 190° to 200° F., certain parts of the milk may be overheated, which gives a scorched or burnt taste to the milk. An automatic temperature control is very essential with this type of heater. The flow of the milk to the machine, as well as its temperature, will fluctuate more or less, and unless there is an accurate automatic temperature control attached there is almost sure to be an unevenness of temperature in the milk as it comes from the heater, even though a man spends his entire time in operating the machine. For example, at a plant using this type of heater with no temperature control, temperatures were taken in each compartment of a positive holder of the milk as it came from the heater and these temperatures varied from 144° to 156° F.

Good results are obtained by using a preheater or a regenerator in conjunction with this type of heater. In this way the capacity of the heater is increased, thus lessening the tax on the machine, and less extreme temperatures can be used. At some plants using this system of pasteurization the milk is preheated to from 110° to 120° F. before it enters the pasteurizer proper; thus the milk has to be heated only 25 or 30 degrees more in the machine. Much more satisfactory and uniform results are obtained in this way. Temperatures obtained with this preheating system are shown in Table 4, plant No. 7.

A combination of this type of heater and a series of vats will produce good results. The milk can be heated to 120° or 135° F. before it goes to the vats, and thus the dangers of overheating can be eliminated. The remainder of the heating will be accomplished in the vats, and the milk will be held in them until it is to be cooled.

*Drum or film heater.*—With some machines of the drum or film type (fig. 7) the milk flows between two or more heating surfaces in a thin film, while in others it flows in a thin film over a revolving drum inside of which is the heating medium. The heating water is kept at the desired temperature either by heating it in a tank outside the machine or by the introduction of steam directly into the machine. The former method is preferable, as there is less chance of overheating the milk. The milk must be kept in motion, and this is usually done by means of a revolving drum. The regenerative principle is used with some machines of this type.

Some of the advantages of this type of heater are:

1. The area of the heating surface is considerably greater than with the "kettle" type, and there is less danger of overheating some of the milk.
2. It is less expensive than some other types of heaters.
3. The machines are durable.

Some of the disadvantages are:

1. Some of the heaters contain several parts and are difficult to clean and to keep in good running condition.
2. They are not especially adapted to increase in capacity by adding additional units.

*Internal tubular heaters.*—With the internal tubular type of heater (fig. 8) the milk passes through a tube inclosed within another tube or in a jacket containing the heating medium. In some of them the outer pipe or jacket is insulated to prevent loss of heat by radiation. The milk flows in an opposite direction to that of the heating medium, and in this way the heat units of the heating medium are economically utilized and the milk is heated without any extreme fluctuations of temperature. The heating medium is hot water, which is heated by the introduction of steam before it enters the coil. As this heating water can be forced through rather rapidly and the area of the heating surface is comparatively large, the temperature of the heating medium need not be much higher at any time than that to which the milk is to be heated.

Some of the advantages of this type of heater are:

1. Simplicity.
2. Some types are comparatively inexpensive.
3. Some types are adaptable to increase in capacity by adding additional units.
4. Durability. There are few parts to get out of repair.
5. Regenerative principle of heating can be utilized, permitting economy of heat and refrigeration.

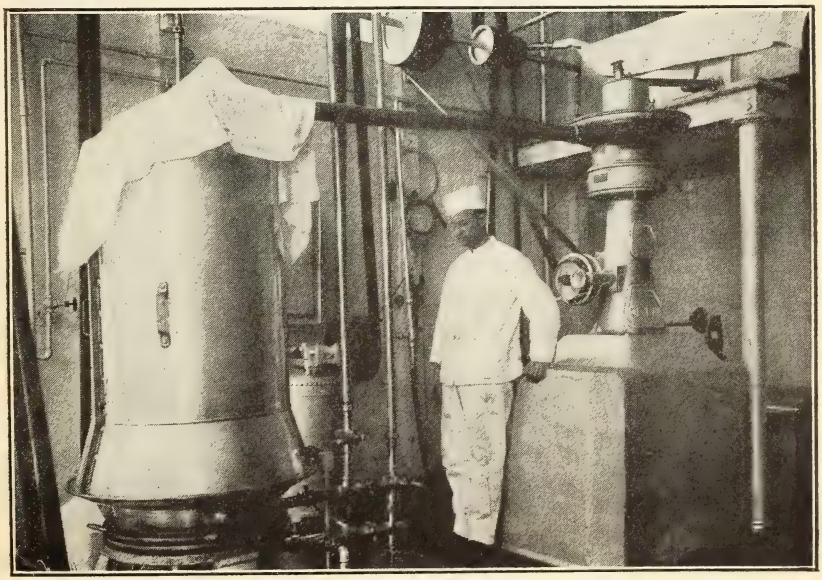

FIG. 7.—Continuous pasteurizer of the film or drum type. Clarifier on right.

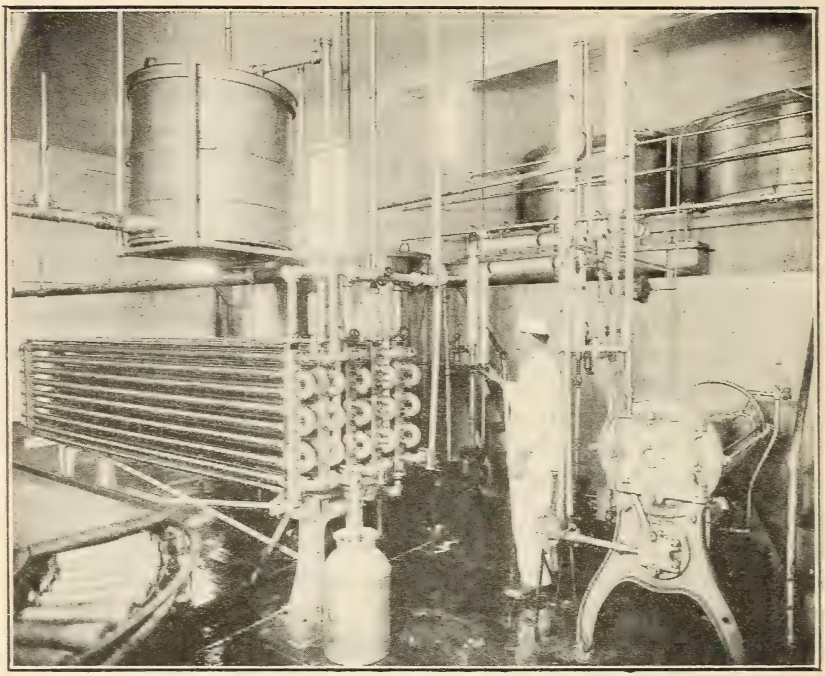

FIG. 8.—Pasteurizer and cooler of the internal-tube type.

6. Easy sterilization. If the ends of the tubes are closed steam can be introduced under pressure and the apparatus thoroughly sterilized.
7. High temperatures of the heating medium not necessary.

Some of the disadvantages of internal tube heaters are:

1. A large quantity of piping to be cleaned.
2. The milk may be agitated considerably by passing from one pipe to another.
3. Some forms are quite expensive.
4. Some types are not adapted to increase in capacity by adding additional units.

It is very important that pumps supplying milk to heaters of this type are not run too fast and that a uniform quantity of milk is allowed to flow to the pump. All machines should have automatic temperature controls for maintaining a uniform temperature.

### HOLDERS.

After the milk is heated to the desired temperature (145° F.) it must be held at that temperature for 30 minutes. The process of holding is usually carried on in an apparatus separate from the heater or cooler.

In general, there are two types of holders, the positive holder and the continuous holder or retarder.

*Positive holders.*—By positive holding is meant that the milk, after being heated to the desired temperature, remains in a certain compartment a definite length of time and is then cooled. Usually the milk is drawn from the compartment and cooled over a separate cooler. Generally the filling and emptying of the compartments of the holder are controlled automatically (fig. 9), but in the case of the batch system, where the vat is used as a holder, the valves are controlled by hand and it is necessary for the attendant to open and close them at the proper time. Some compartment holders also are controlled by hand valves. Holders should be so insulated that little heat is lost while the milk is being held, and with positive holders of the automatic type it is very essential for the valves to be accurate. The valve of the compartment to be filled should always be closed tight before the milk begins to flow in; otherwise some of the milk will pass through without being held. With any holder it is important that all pipes or " pockets " in which the milk is held during the heating or holding processes be well insulated, so that the holding temperature can be maintained.

*Continuous holders.*—With continuous holders or retarders the milk passes through the apparatus in a continuous flow. This flow

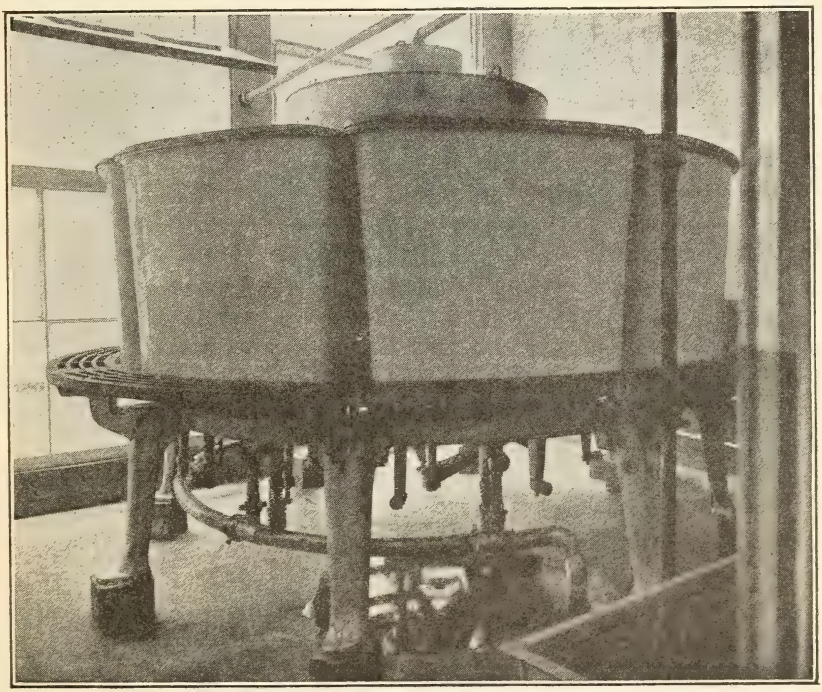

FIG. 9.—Automatic holding device for the pasteurization of milk.

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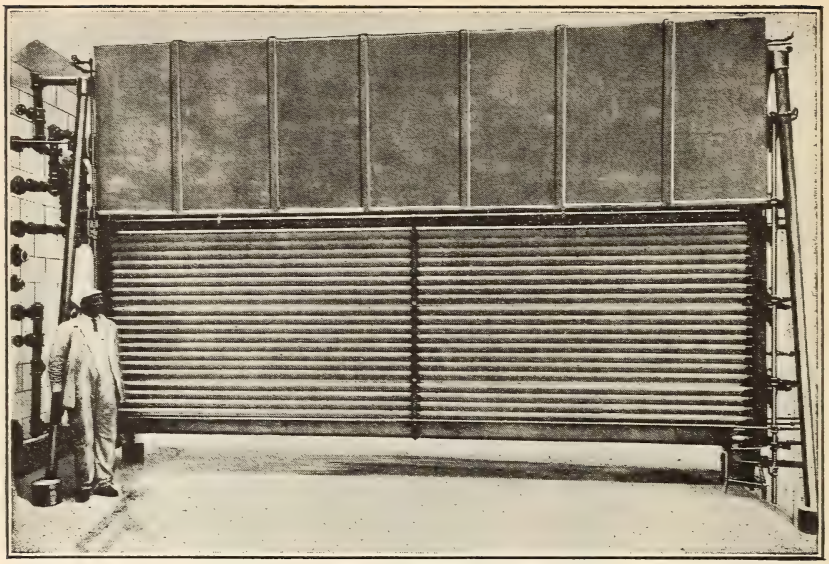

FIG. 10.—Open or surface milk cooler.

of milk is retarded in its course by some form of obstruction, such as baffle plates, or in some types it passes through a series of winding pipes. It is supposed to take half an hour for the milk to pass through the holder. Some continuous holders consist of a series of two or more tanks, the milk flowing from one tank as soon as it is full to the next, and half an hour is required for it to go through all the tanks.

Good results have been obtained with many holders of the continuous type. The danger with such holders, however, is that some particles of the milk may not be held so long as others and that the milk may be forced through the apparatus and none of it held the proper length of time. Tests made on several retarders of one type have shown that some of the milk was held only 10 minutes. Tests should be made on all such apparatus to ascertain whether the milk is being properly held, and retarders that do not do accurate work should not be used.

Of 237 plants surveyed in the year 1916, 15 were using the "flash" system, 24 were using "retarding" systems, and 198 were using positive holders.

### COOLERS.

In general there are two common types of coolers—the open-surface tubular cooler and the internal-tubular cooler. With the open-surface cooler the milk passes over the tubes in a thin film. The cooling medium passes through these tubes on the inside. There is usually water in the first sections and brine or direct-expansion

ammonia in the remaining sections. Where the regenerative system of pasteurization is used the cool milk is often allowed to pass through the inside of the first sections of the cooler. With the open-surface cooler the milk is exposed to the air in the room, and for that reason the air should be kept pure. It is important that the cooler be of sufficient capacity to cool the required quantity of milk. When the cooler is not large enough there is a tendency for the operator to allow the milk to go over the cooler too fast for proper cooling.

The internal-tubular coolers are constructed on the same principle as the internal-tube heaters; that is, the milk passes through a pipe which is itself inclosed in a pipe or jacket containing the cooling medium. The length of tubing required in cooling coils is about double that of heating coils. With this type of cooler the milk does not come into contact with the air at any time. A claim made for the open cooler is that the milk is aerated, while with the internal-tube cooler bad odors have no chance to escape. On a commercial scale, however, little trouble has been found from this source. There is no loss of milk from evaporation with the internal-tube cooler, while there may be considerable loss from this source with the open cooler, especially if the cooler is in a draft.

If the open cooler is covered, contamination from the air will be reduced; however, it is more desirable to have pure air in the room where the cooler is located, as it requires considerable care to keep these covers clean, and they are often clumsy to handle. If covers are used, the sterilization of the cooler is made easier.

It is much easier to sterilize the internal-tube cooler than the open-surface cooler. If steam is introduced into the internal cooler and the apparatus closed, it can be thoroughly sterilized. One way to sterilize the surface cooler is to admit steam to the inside of the tubes and at the same time run hot water over the outside of the cooler. The hot water will be vaporized and quite thorough sterilization will result. Another method which is perhaps more satisfactory is to close the covers tightly over the cooler and introduce live steam.

In some forms of regenerative pasteurization the incoming milk will pass through the first few tubes of the cooler. This saves steam, but the tubes are difficult to clean.

The open-surface coolers should be so constructed that water can be used in the top sections and brine or direct-expansion ammonia in the bottom sections. The capacity should be great enough to cool the milk as fast as it comes from the holder. The tubes should not be too long in comparison with their height. When the tubes are too long their whole length sometimes is not covered by the milk, and refrigeration is wasted. In some cases, however, it is necessary to

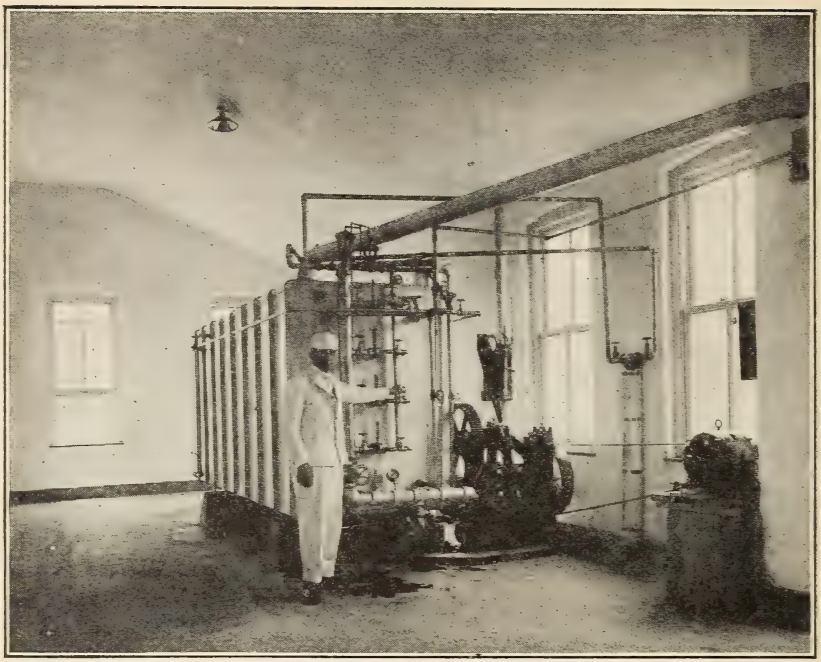

FIG. 11.—In-the-bottle pasteurizer, showing pumps which force the sprays of hot water over the bottles.

have the cooler considerably longer than it is high, so that the available elevation will allow gravity flow of the milk. Table 7 shows the methods of cooling used at various plants. Sometimes coolers are made in three sections, water being used in two of them and brine or direct expansion in the third. In this way better use of the water is made. At one plant the temperature of the milk from the first water section was 78° F., from the second 64° F., and from the brine coil 34° F. The second section cooled the milk from 78° to 64° F., thus saving considerable refrigeration. (See fig. 8 for internal cooler.)

### IN-THE-BOTTLE PASTEURIZATION.

With the "in-the-bottle" system of pasteurizing, which has been developed within recent years, the milk is pasteurized after it has been put into the bottles. The bottles of milk, in cases, are placed in a compartment and heated to the desired temperature, held, and cooled. With some types the milk is heated, held, and cooled in the same compartment, while in others the bottles, after being removed from the cases, pass slowly through the machine, being heated at the beginning and cooled at the end of the process. With this system it takes 30 minutes for the bottles to travel from the point where they

have been heated to the desired temperature to the point where cooling is begun. The heating with the in-the-bottle pasteurizer is usually accomplished by passing sprays of hot water over the bottles. (See figs. 11 and 12.) Either a special cap is used on the bottle or the bottles are covered with a specially constructed pan. In the latter case the hot water usually flows through small holes in this pan and forms a thin film around the bottles. Where the special cap is used the pans are not required. The cooling is accomplished by changing from hot water to cold. After the milk is heated, held, and cooled it may remain, in some types, in the machine and be kept at a low temperature until time for delivery. With some types of the in-the-bottle pasteurizer the milk in the bottles is heated by live steam and the cooling is accomplished by immersing the bottles in clean, cold water. With other types the bottles are heated by immersing in vats containing hot water.

FIG. 12.—Front view of in-the-bottle pasteurizer, showing the fine sprays of hot water used in heating the milk.

Some of the advantages of pasteurizing in the bottle are:

1. Operation is comparatively simple.
2. For a small dealer the first cost is comparatively small.
3. The apparatus is durable.
4. There is little chance of recontamination of the milk after pasteurization, provided water-tight caps are used and bottles do not have to be recapped.
5. The bottle as well as the milk is heated.
6. In some cases small plants can save space by its use, as the pasteurizer serves also as a cold-storage room.
7. No apparatus, pumps, or pipes to clean.

Some of the disadvantages of in-the-bottle pasteurization are:

1. The system is rather slow for a large commercial plant. For a small plant, however, this objection may not be serious.
2. Considerable extra steam and refrigeration are required, as it is necessary to heat and cool the bottles, caps, and cases, in addition to the milk.
3. During the heating process the milk will expand in the bottle, so that unless a bottle of extra capacity or a special and more expensive cap is used, many of the bottles will have to be recapped after cooling, because the expansion of the milk will force the cap out. It is advisable to use a bottle of extra capacity, since recapping, besides causing considerable trouble, may contaminate the milk. Where extra-sized bottles are used they contain full measure of milk, but there is some empty space between the top surface of the milk and the cap to allow for expansion during heating. Such bottles do not appear full when delivered and thus may cause some complaint among customers.

### SYSTEMS OF PASTEURIZING USED.

Various systems of pasteurizing used at 237 plants are shown in Table 5. It will be noted that the vat and in-the-bottle systems are more common with the smaller plants, while film and tubular types are more common with the medium-sized and large plants. Seventy-five of the 237 plants were using temperature recorders, and 67 plants were using temperature regulators.

One of the important factors in a pasteurization system is an even flow of milk into the pasteurizer and also from the holder to the cooler. If the flow is constant throughout the apparatus more accurate results will be obtained. At some plants where a gravity system is used a float valve is attached to the apparatus. This valve will allow only a certain quantity of milk to flow to the pasteurizer per hour. A similar valve placed at the outlet of the holder will allow the same quantity to go from the holder per hour. In this way more nearly uniform results are obtained in heating and holding.

TABLE 5.—*Types of pasteurizers used at 237 plants of various sizes.*

| Milk handled daily. | Vat. | Tubular. | Film or drum. | Kettle. | In the bottle. | In the can.[4] | Total all types. | Number of these plants using the flash system. |
|---|---|---|---|---|---|---|---|---|
| *Gallons.* | | | | | | | | |
| Up to 100 | [1] 4 | ..... | ..... | 1 | 4 | 3 | 12 | ..... |
| 101 to 250 | [2] 7 | ..... | 1 | 2 | 5 | ..... | 15 | 1 |
| 251 to 500 | 23 | 1 | 2 | 6 | 2 | 1 | 38 | 4 |
| 501 to 1,000 | [3] 24 | 9 | 8 | 10 | 1 | ..... | 52 | 4 |
| 1,001 to 2,000 | 14 | 12 | 12 | 7 | 3 | ..... | 48 | 3 |
| 2,001 to 4,000 | 8 | 12 | 9 | 10 | 1 | ..... | 40 | 2 |
| 4,001 to 6,000 | 2 | 4 | 12 | ..... | ..... | ..... | 18 | 1 |
| 6,001 to 10,000 | 2 | 3 | ..... | ..... | ..... | ..... | 5 | ..... |
| Over 10,000 | 1 | 3 | 4 | 1 | ..... | ..... | 9 | ..... |
| Total | 88 | 44 | 48 | 37 | 16 | 4 | 237 | ..... |

[1] Two of these were starter cans.
[2] One was the "spray" vat system.
[3] Two were the "spray" vat system.
[4] Cans set in vat of water which is heated with live steam.

### TEMPERATURE REGULATOR.

Automatic temperature control is essential to the pasteurizing plant. It is very difficult and often impossible to control the temperature by means of hand valves, but there are many automatic devices on the market which control the temperature with great accuracy. In a plant without an automatic control a large proportion of a man's time must be spent at the steam valve if the temperature is to be kept within proper limits. During the process of pasteurization one man has to spend the greater part of his time there, and even then it is very difficult to prevent frequent variations in temperature. Not only may the cream line be injured by such irregular temperatures, but the results, both from bacteriological and chemical points of view, are unsatisfactory.

### RECORDING THERMOMETER.

The recording thermometer is another appliance that should be used in all plants where milk is pasteurized. By means of this device a record of the temperatures of the milk during the whole day's run is made. Each day the superintendent has a report which shows the temperature to which the milk is heated at any period of the process and also, within certain limits, how long it was held at the pasteurizing temperature. Thus, although not necessarily present himself, he can keep a reliable check on the operator. These records can also be shown to complaining customers or to health officials as evidence as to how the milk was pasteurized.

Recording thermometers must be tested after being set up and checked with an accurate hand thermometer. They may get out of adjustment and should be checked up frequently.

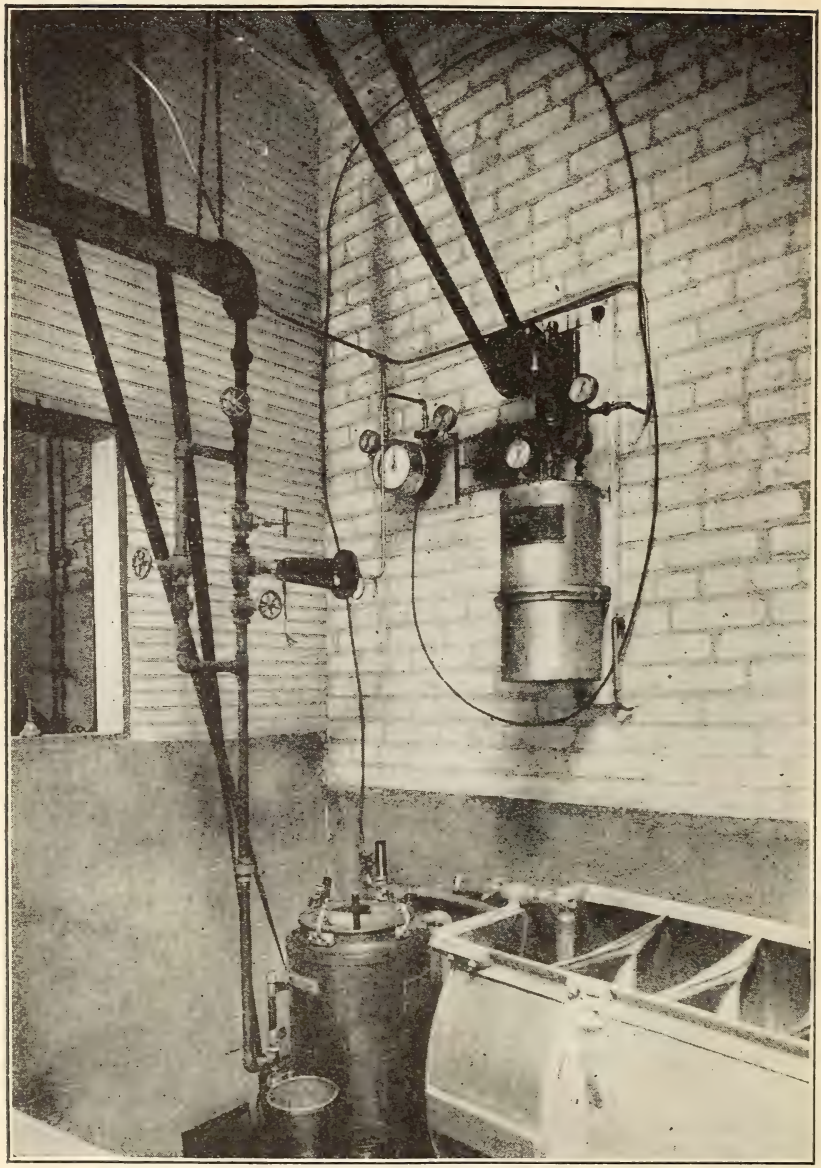

FIG. 13.—Temperature controller for heating milk to desired temperature in pasteurization.

There should be a supply tank between the milk coolers and the fillers. If anything happens to the fillers it will not be necessary then to shut down the pasteurizer. The supply tank will equalize the flow of milk from the pasteurizers to the fillers.

## BOTTLE FILLERS AND CAPPERS.

In order to put the milk into bottles for the trade, bottle fillers and cappers are required. There are many types. At some small plants the bottles are filled by hand or by the use of a dipper. This is very unsatisfactory even for a small plant, both because of the chance of contamination and the danger that the milk is not uniform in butterfat content. Hand filling is also slow and tedious.

Bottle fillers used by the smaller dealers consist of a tank mounted on a metal framework and containing valves either at one or both ends of the tank. The smaller ones have four valves at one end, while the next larger-sized machines have four valves at one end and five at the other. Quarts may be filled at one end while pints are being filled at the other end. With the next size of filler a full case of bottles is filled at one operation (figs. 15 and 16). When the bottles are full the case goes on to be capped either by hand or

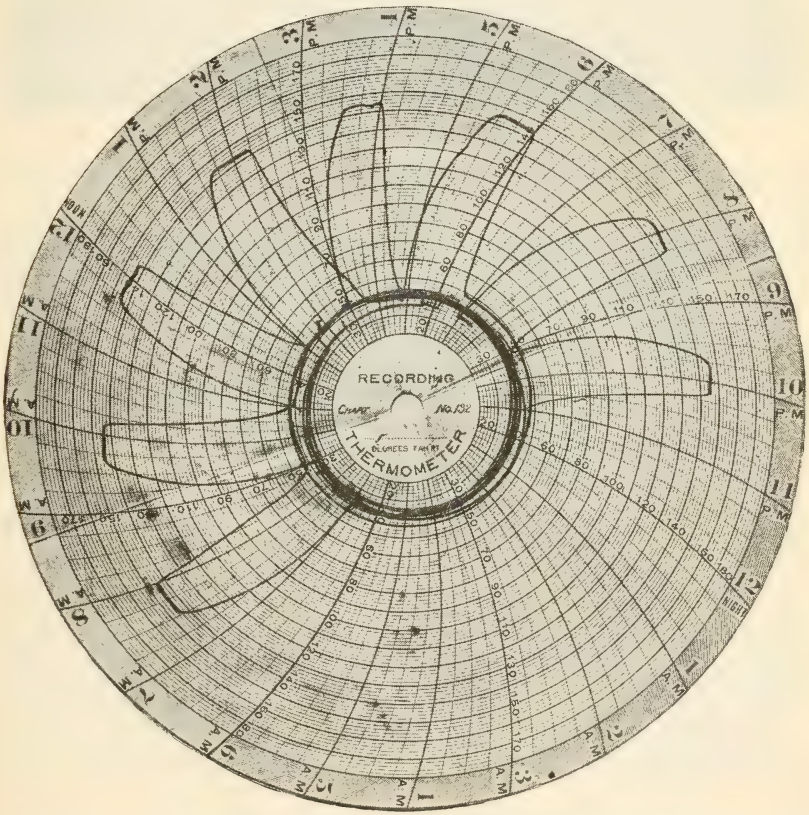


FIG. 14.—Chart for temperature recorder, showing temperatures and time of heating, holding, and cooling eight different batches of milk. In-the-bottle system of pasteurization was used.

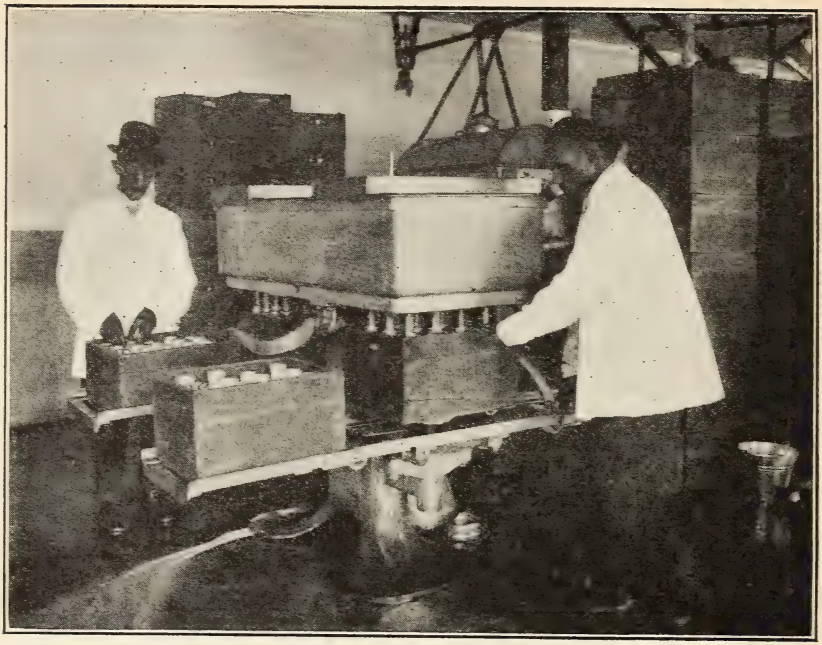

FIG. 15.—Filling bottles by machine of lever type and capping by hand.

machine. Some fillers of this type have 12 valves at one end of the tank and 20 at the other, so that a case of quarts and pints can be filled as desired, and both can be filled at the same time by having a man to operate each end of the machine. The capping machines cap one row of bottles or a whole case, depending on the type of machine, at one stroke of the lever.

### AUTOMATIC SINGLE-BOTTLE AND ROW FILLERS.

So-called rotary fillers and cappers (fig. 17) have been introduced in recent years and are used extensively. This filler consists of a circular tank with valves similar to those of the other types of fillers. The bottles are removed from the cases and placed on a revolving carrier, which brings them under the valves of the tank. Each bottle is automatically raised as it comes under the valve and the milk flows into it. When the bottle has traveled the full revolution of the tank it is automatically lowered and the valve closes. By revolving a full revolution the bottles have ample time to be filled. The bottles are then carried to the capper, which caps them automatically. With large machines of this type one man is required to take bottles out of the cases and feed them to the filler while another man removes the filled and capped bottles from the machine and returns them to the cases. There are several sizes of these

machines, and the tanks have from 8 to 12 or more valves. From 24 to 72 or more bottles can be filled and capped per minute, depending on the size of the machine.

With the so-called row fillers the bottles are also taken from the case and placed under the valves by hand. They are partially filled under the first set of valves and move on to have the filling completed by a series of additional valves. After capping, which is done by machine, full bottles are removed and replaced by hand in the case.

Some of the advantages of these types of fillers are:

1. Simplicity.
2. The bottles can be inspected when filled before being returned to the cases.
3. The capacity of the plant can be increased gradually by adding more units of the same capacity without decreased economy in the use of labor.
4. Small floor space is required.

### AUTOMATIC CASE FILLERS AND CAPPERS.

Some of the large plants have automatic power fillers and cappers (fig. 18). Usually the fillers and cappers are operated by electric power, and in some cases the valves are operated by hydraulic pumps. With these machines a full case of bottles is filled and capped automatically. All the operator does is to feed the cases of

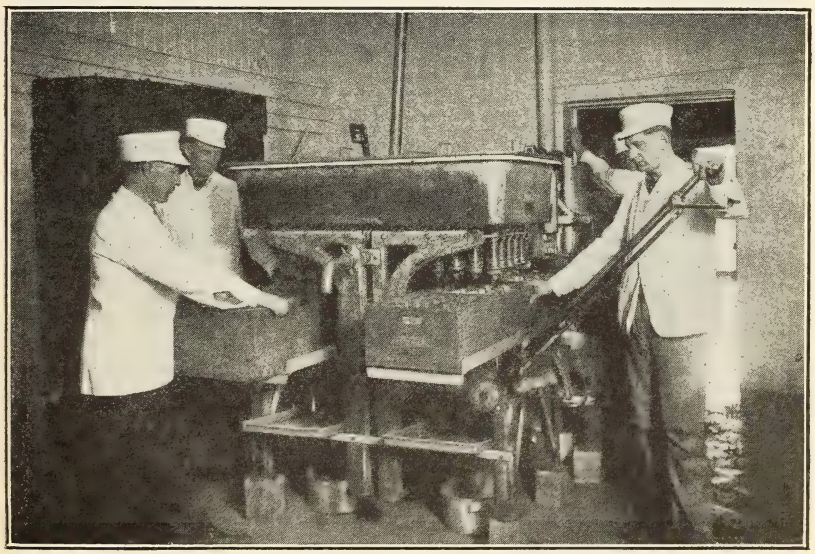

FIG. 16.—Machine filling and capping bottles.

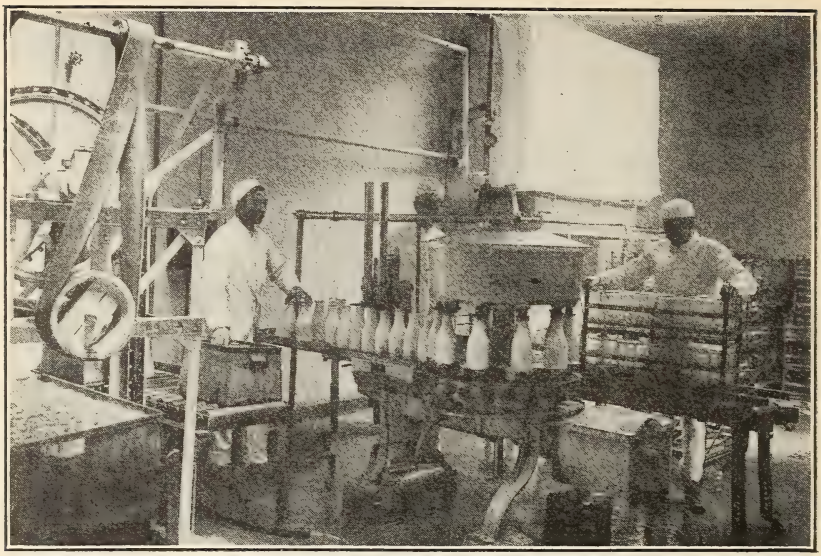

FIG. 17.—Rotary filling and capping machine.

empty bottles to the machine and take them away filled and capped. From 5 to 10 cases a minute can be filled and capped with these

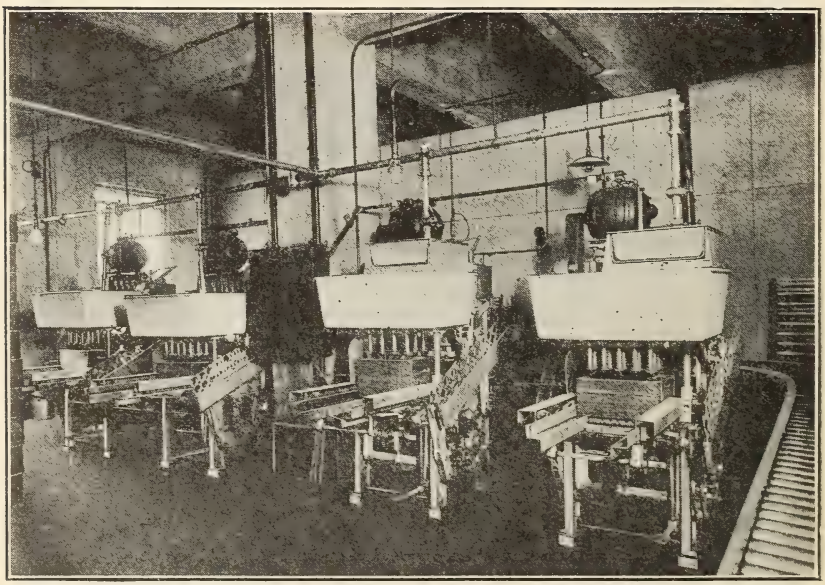

FIG. 18.—Type of automatic filling and capping machine.

machines. They are more expensive, and some types are difficult to operate. Being more complicated they require careful attention in order to keep them in good working order.

## BOTTLE WASHERS.

There are several types of bottle washers. At some small plants the bottles are simply swabbed out with a hand brush and then rinsed. The next advance over this process is the washing of bottles

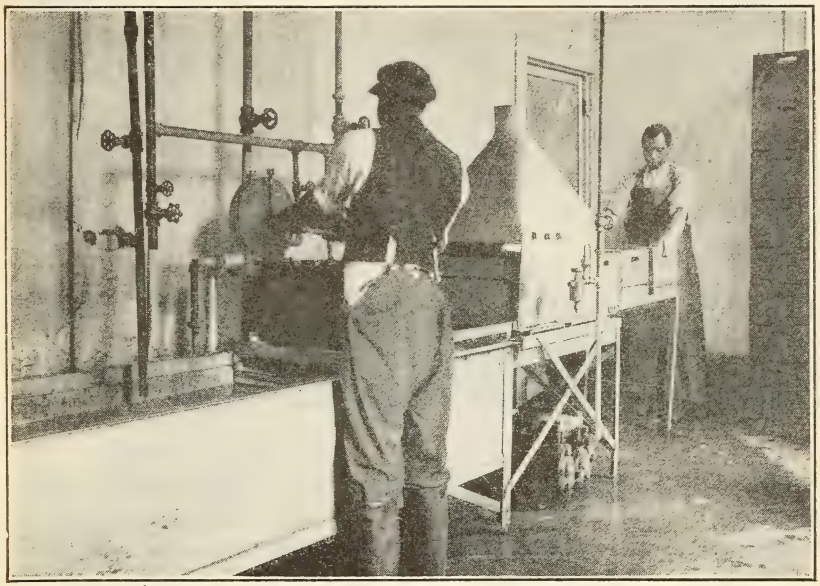

FIG. 19.—Turbine-brush bottle washer. Bottles are rinsed by sprays of boiling water forced into them by pump.

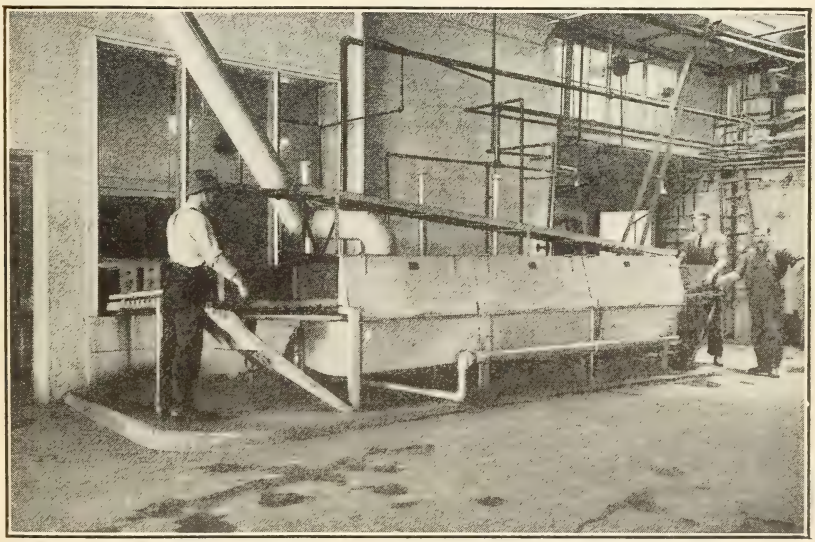

FIG. 20.—An automatic bottle washer. As high as 2,000 bottles per man per hour were washed with this type of machine.

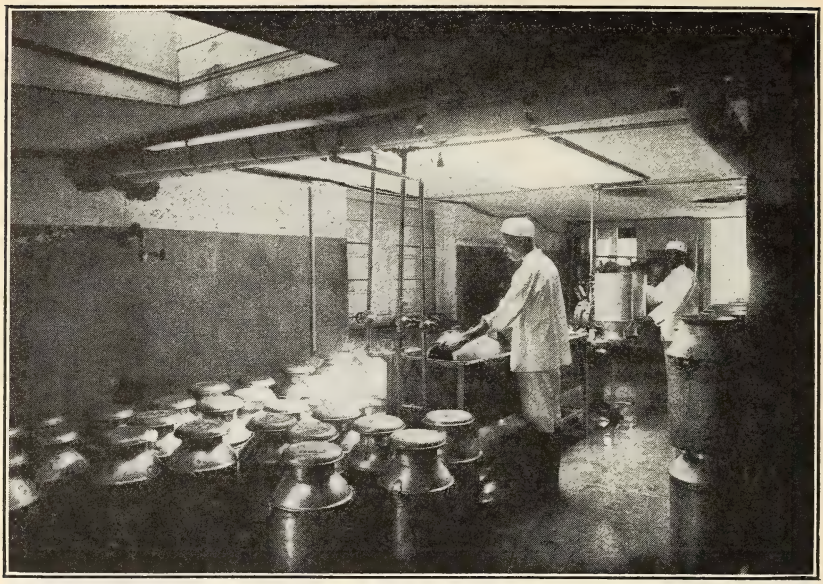

FIG. 21.—Washing, steaming, and drying cans.

on a revolving brush. The brush is made to revolve by means of a steam turbine, engine, or motor, and in a few cases a water turbine. After the bottles are washed they are returned to the case and rinsed and steamed. With some machines this is done by means of a two-way valve through which first hot water and then live steam is forced into the bottles. Other machines are provided with a pump which pumps water at a high temperature into the bottles. The bottles should be inverted in the cases after washing; otherwise the water on the cases will drip into the bottles below when the cases are stacked.

At most large plants automatic power washers are used. There are several different types of these power washers, but the most common one consists of a series of tanks containing water at various temperatures. The first tank contains a solution of alkali or washing powder. By means of powerful pumps these solutions and water are forced through jets into the bottles in the cases. The first solution is warm, and the solution or water in each succeeding tank is hotter than in the one before. The last water to be forced into the bottles is almost at the boiling point, and the bottles may then receive a spray of steam. Temperatures observed in various tanks at four plants are shown in Table 6. One man usually feeds the cases of bottles into this machine while another man takes them out at the other end. Very dirty bottles can not be cleaned by such machines, but should be washed first with a brush machine and then sent through the automatic machine for rinsing and steaming.

TABLE 6.—*Temperatures observed in various tanks of automatic jet bottle washers.*

| Plant No. | Tank 1. | Tank 2. | Tank 3. | Tank 4. |
|---|---|---|---|---|
| | °F. | °F. | °F. | °F. |
| 1 | 90 | 120 | 160 | 200 |
| 2 | 100 | 120 | 140 | 170 |
| 3 | 110 | 150 | 180 | ..... |
| 4 | 90 | 140 | 180 | ..... |

It is very important that the proper temperature be maintained in the various tanks. The temperature in the first tank must not be so high as to break the bottles, and it should be increased in each tank so that the final tank will be kept at a temperature near the boiling point. Care must also be taken to have the proper solutions in the various tanks. The first tank of large machines contains a strong alkali solution, the second a milder solution, and the remaining tanks rinsing water.

## CAN WASHERS.

Can washers are of various types. Some of them are brush machines while others operate on the same principle as the automatic bottle washers described, that is, by forcing solutions of washing powder, hot water, and steam into the cans. In order to facilitate drying, some of these machines also blow a blast of air into the can after steaming.

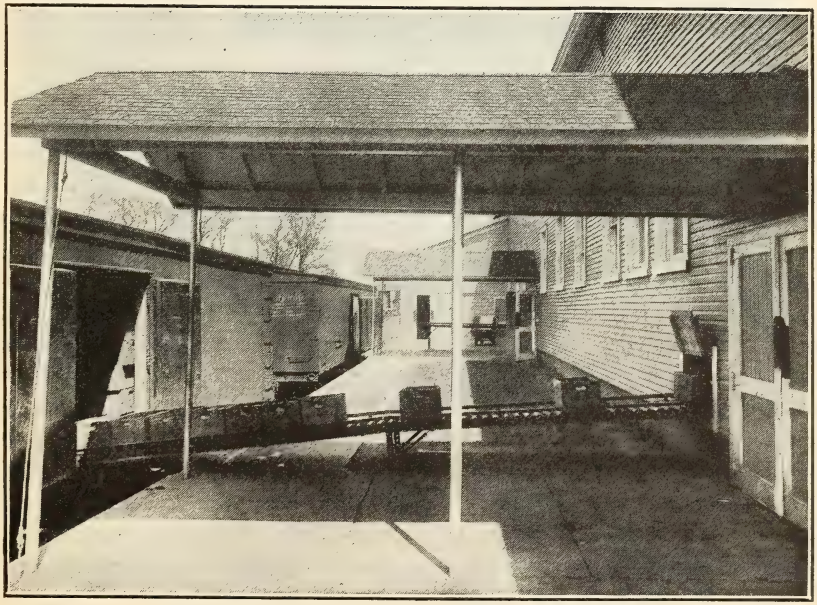

FIG. 22.—Roller conveyers as labor-saving devices.

Dealers should give considerable attention to the question of washing the cans. If they are allowed to go back unwashed it is a very difficult if not an impossible task for the farmer, with his limited facilities, to clean them properly. It does not matter what method is used, so long as the cans are well rinsed, sterilized, and dried. The drying of the cans is an important factor. It not only leaves the can in a more sanitary condition but preserves its life by preventing rust. The cover should also be thoroughly cleaned and sterilized, but should not be put on the can until the latter is dry. When the covers are not put back on the cans immediately the cans should be kept in a clean place where there is no dust or contamination. The covers should be placed tightly on the cans before they are returned.

The milk dealer must have a machine that will do rapid work, but the main result to be obtained is a clean, sterile, and dry can, regardless of the method used. Many of the machines on the market do not steam the cans long enough. Some dealers get good results by washing the can in a sink with a hard brush, then rinsing and placing it over a jet which blows live steam into it. If the steam is allowed to go into the can long enough the can will dry in a few moments after being removed. Each can should receive live steam for at least 45 seconds.

## LABOR-SAVING DEVICES.

Considerable labor can often be saved by the use of labor-saving devices, such as elevators and conveyers. Some conveyers operate by gravity, while with others power is used. This equipment is expensive, and, of course, only such quantity should be purchased as can be used economically. Many steps and much labor, however, can be saved by the proper use of these devices. A conveyer to run cans of milk from the receiving platform to the dump tanks often saves much labor. A conveyer from the clean-bottle storage room through the bottle-filling room to the cold-storage room will, in many plants, save at least one man, while a conveyer from the cold-storage room to the loading platform will greatly expedite the loading of the delivery wagons and save labor at many plants. The same conveyer can often be used for two purposes at the same plant; the track that is used to convey the milk into the storage room during the day can be used at night in loading the delivery wagons. At some plants a conveyer is used to convey the cases of empty bottles from the receiving platform to the bottle-washing room, thus preventing congestion on this platform and expediting the work. The economy of these labor-saving devices is shown in Tables 1, 2, 3, and 4 in Department Bulletin 849, City Milk Plants.

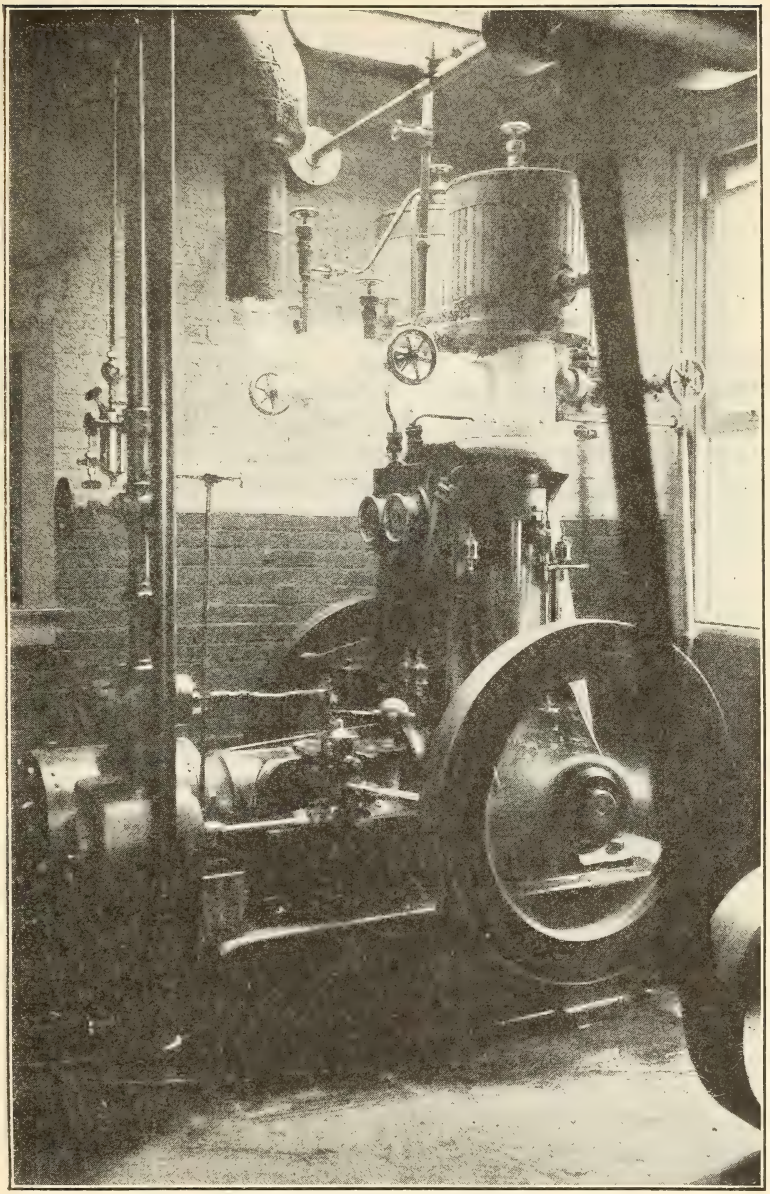

FIG. 23.—Compression type of refrigerating machine.

## POWER PLANT.

The power plant should be in a separate building if possible. If this is impracticable, it is well to have it in the basement of the plant. If the power plant must be adjacent to the rest of the plant,

it is important that the boiler room be far enough away and so inclosed that dirt, soot, and fumes will not reach the milk-handling rooms. The power plant should be of ample capacity, so that none of the equipment or apparatus need be forced. It may be advisable for large plants to have two refrigerating machines and two boilers. Considerable power may be saved at certain times of the year by operating only one of the machines when the full capacity of refrigeration is not needed. By having two boilers, one can be cleaned or repaired without shutting down the plant.

### STEAM OR ELECTRIC POWER.

Whether a steam engine or electric motors should be used will depend largely upon the costs of current and coal. The use of motors has several advantages, and direct-connected motors for each machine are advisable wherever possible, although where several machines are grouped together less power will be required if only one motor is used to run the shafting for all the machines. At large plants electric current to run the motors can often be generated for much less than it can be bought. Some of the advantages of motors are:

1. Simplicity of operation.
2. Cleanliness.
3. Power is used only when machine is operated.
4. Small space required.
5. Power used in operating a machine may be determined accurately at any time.
6. Obviates insanitary hangers, shafting, and pulleys.

Some of the advantages of the use of steam engines in milk plants are:

1. The exhaust steam can be utilized.
2. The source of power is under the control of the milk plant.
3. A steam boiler must be used anyway to supply steam for hot water, pasteurizing, sterilizing, and for heating the building.

Whatever power is used it is well to have an auxiliary system, so that if anything happens to one system the plant will not have to be shut down. A plant using motor power should have an engine for an emergency, while a plant using engine power should either have an extra engine or some electric motors installed.

### ARTIFICIAL REFRIGERATION.

Most large plants use artificial refrigeration, but there are many smaller ones that still depend upon ice. Individual conditions will determine which will be more economical to use.

The methods of producing artificial refrigeration are familiar to most milk dealers. They are fully described in United States Department of Agriculture Bulletin 98.

In some plants the refrigeration medium is expanded directly into the cooling coils, while in others brine is used. (The brine is kept cold by passing the ammonia pipes through it.) The brine is pumped into the cooling coils, or it may remain in the tank, thus keeping the room cool a long time after the refrigerating machine has been stopped. Both the direct-expansion ammonia system and the brine system have their advantages. In large plants where refrigeration is needed continuously for cooling the milk and the cold-storage room the direct-expansion system is more economical than the brine storage. In small plants where the cooling is done in a comparatively short time it is more economical to use the brine-storage system of refrigeration, owing to the fact that a smaller compressor may be used and refrigeration for use in cooling the milk and storage room may be stored in a large quantity of brine and held for quick action when needed. However, when the larger part of the day is consumed in pasteurizing, so that uniform refrigeration is required, the direct-expansion system is often used. In order that the refrigerating machine need not be run continuously most plants use brine tanks in the cold room, so that the room can be kept cold for a considerable time after the machine is shut down.

TABLE 7.—*Systems of cooling milk at 84 milk plants.*

| Quantity of milk handled daily. | Number of plants using direct-expansion ammonia. | Number of plants using the brine-circulating system. | Number of plants using ice water. | Total. |
|---|---|---|---|---|
| 250 or less gallons | ..... | 1 | 5 | 6 |
| 251 to 500 gallons | ..... | 2 | 10 | 12 |
| 501 to 1,000 gallons | ..... | 10 | 6 | 16 |
| 1,001 to 2,000 gallons | 3 | 12 | 2 | 17 |
| 2,001 to 5,000 gallons | 7 | 15 | 1 | 23 |
| 5,001 to 10,000 gallons | 2 | 6 | ..... | 8 |
| Over 10,000 gallons | 1 | 1 | ..... | 2 |
| Total | 13 | 47 | 24 | 84 |

There are many advantages in the use of brine over direct expansion alone in a milk plant, some of which are:

1. The system is more elastic; the brine can be stored up for cooling after the refrigerating machine has been shut down or in case of a breakdown.

2. There is less danger of freezing the milk on the cooling pipes with the brine system of cooling.

3. Pipes need not be so strong as those required for the direct-expansion system of cooling milk.

4. There is less danger of leaks in the pipes than if direct expansion is used, and therefore less danger of tainting the milk.

5. For small or medium-sized plants the machine would have to run longer if direct expansion only were used, because with the brine system the machine may store up refrigeration in the brine to last for 10 or 12 hours, while only 2 or 3 hours are required for cooling the milk.

The direct-expansion system is the most economical at plants where it is necessary to run the machine continuously, as less refrigeration will be lost if it goes directly to the cooler than when it goes through the secondary brine medium.

Many plants use a combination of the two systems. Direct-expansion coils are used in the cold room and brine is circulated from a tank, usually in the cold room, through the milk cooler.

Whether direct expansion or brine is used in cooling the milk, it is usually more economical to use water in the first few coils of the cooler, as refrigeration is thus saved. In some plants, instead of using brine or direct expansion for cooling the milk, refrigerated water is used; that is, water for cooling is cooled by means of brine coils or direct-expansion coils. In this way the temperature of the cooling medium is accurately regulated and extreme temperatures are not required.

Under ordinary circumstances artificial refrigeration is cheaper than the use of ice for medium-sized or large plants. With careful operation there is very little waste of refrigeration, the original cost of machinery and the labor and power being the chief items of expense. In a medium-sized or small plant, however, it is often a perplexing problem to the dealer whether to install an artificial refrigerating plant or to depend upon ice. In deciding this question it is necessary to consider such factors as the price of ice, quantity required each day, labor of handling, the disadvantages incident to its use, and the certainty of a supply of ice. Then come the questions of size, initial cost, and the cost of operation of a refrigerating plant which would accomplish the same result.

In some cases it may be necessary to increase the size of the boiler and of the engine, which should, of course, be large enough to run the compressor while the pasteurizer, bottle washer, and other machinery are being operated. If electric power is to be used, the size of the boiler need not be considered.

In comparing the cost of artificial refrigeration with that of ice it should be remembered that in many cases the former is of greater value than can be estimated, on account of the better results obtained, for when ice is used it is often difficult to maintain a temperature low enough to keep the milk in proper condition.

Some of the disadvantages of the use of ice are the following:

1. Cost of ice is often high.
2. Extra work required in handling.
3. Mold and slop incident to its use.
4. Moist atmosphere caused by its use.
5. Difficulty of obtaining temperature below 50° F. in storage room.
6. Waste caused by melting in handling.
7. Ice not always obtainable.

A supply of natural ice is uncertain, depending on weather conditions; some years there is a shortage, and in the South, of course, natural ice can not be obtained. Aside from the possibility of accident a refrigerating machine can be depended upon to supply the requisite amount of refrigeration at all times. Furthermore, it results in cool, dry air in the storeroom, produces lower temperatures than ice, and permits more accurate control of temperature. Where artificial refrigeration is used less ice is required on the delivery wagons, since the original temperature of the milk is lower. Many plants find it profitable to manufacture ice for sale as well as for their own use. This requires very little extra labor and overhead. and yields an additional cash income.

#### USE OF EXHAUST STEAM.

If exhaust steam from the engine is allowed to escape unused a valuable by-product is wasted and the coal bill is correspondingly high. Exhaust steam can be used successfully for pasteurizing milk or cream, heating boiler-feed water and water for washing purposes, and for heating the building. By using an exhaust-steam water heater an abundant supply of water at a temperature of about 200° F. is made available.

If a plant has an engine and in pasteurizing uses the exhaust steam instead of live steam direct from the boiler, the cost of the steam for heating the milk and pasteurizing is practically eliminated. Generally the exhaust from the engine will furnish all the necessary heat. Therefore, in figuring the size of the boiler required, at a plant using an engine to run the pasteurizers, bottle washers, and other apparatus required in the ordinary retail milk plant, the amount of steam to run the engine only need be considered, if the exhaust steam is utilized for pasteurizing.

To heat 300 gallons of milk from 60° to 145° F. requires about 30 pounds of coal, and with that quantity of milk handled daily an exhaust-steam heater would effect an annual saving of more than 5 tons of coal. In case the water from the heater is too hot for the type of pasteurizer used, the temperature should be regulated automatically.

The equipment for utilizing the heat in the exhaust steam in a medium-sized plant is simple and inexpensive.[2] Information in regard to these heaters can be obtained by writing to the Dairy Division, United States Department of Agriculture, Washington, D. C.

The water used in cooling the milk should be saved and not run down the sewer, as is done in many plants. By piping it back to the heater or to a tank, not only would the water itself be saved but also a considerable quantity of coal. Much water in a milk plant can be

[2] See United States Department of Agriculture Bulletin 747.

used many times in order to get the most use out of both the water and the heat it contains.

## COST OF PLANT EQUIPMENT.

Investments in plant equipment at 125 plants of various sizes are shown in Table 8. While there is considerable variation in the investment at plants of the same group, some idea can be obtained of the amount of money that is invested in plant equipment. The plants are in various parts of the country.

TABLE 8.—*Investments in plant equipment and machinery for plants of various sizes.*[1]

| Quantity of milk handled daily. | Number of plants. | Average number of gallons handled daily. | Average investment in plant equipment. | Variation. | Average equipment investment per 100 gallons handled daily. | Variation. |
|---|---|---|---|---|---|---|
| | | *Gallons.* | | | | |
| 100 or less gallons | 8 | 71 | $932 | $500– 1,311 | $1,308 | $625–1,714 |
| 101 to 250 gallons | 16 | 189 | 1,983 | 400– 5,000 | 1,048 | 212–2,500 |
| 251 to 500 gallons | 29 | 399 | 4,864 | 1,181– 15,700 | 1,219 | 348–3,140 |
| 501 to 1,000 gallons | 23 | 782 | 9,177 | 3,200– 20,000 | 1,172 | 400–2,500 |
| 1,001 to 1,500 gallons | 15 | 1,296 | 16,338 | 4,000– 33,008 | 1,261 | 333–3,182 |
| 1,501 to 2,000 gallons | 9 | 1,822 | 26,972 | 7,500– 60,000 | 1,480 | 469–5,000 |
| 2,001 to 3,000 gallons | 5 | 2,597 | 29,268 | 10,000– 47,856 | 1,127 | 260–2,175 |
| 3,001 to 5,000 gallons | 9 | 4,094 | 45,200 | 10,737–100,000 | 1,104 | 268–2,000 |
| 5,001 to 10,000 gallons | 5 | 8,275 | 123,800 | 30,000–265,000 | 1,496 | 558–2,650 |
| Over 10,000 gallons | 6 | 17,298 | 168,019 | 82,000–537,000 | 971 | 639–1,344 |
| | 125 | 2,112 | $24,475 | 400–537,000 | $1,159 | $212–5,000 |

[1] Based on 1916 prices.

## LISTS OF EQUIPMENT REQUIRED FOR VARIOUS-SIZED PLANTS.

On the following pages are lists of the principal equipment required for plants of various sizes and the approximate total cost. These figures on cost are given only as a guide for comparison. The cost of the equipment will depend a great deal on the type of machinery selected, kind of contract made, and the character of the business. As prices are continually changing only approximations can be made as to the cost of equipment. The number of milk cans and bottle cases required will depend upon the individual plant, but in these lists are given the approximate quantity that would be needed.

*Principal equipment for plant of 100 gallons' capacity.*

1 platform scales.
1 pasteurizer (100-gallon vat).
1 temperature recorder.
1 sanitary milk pump.
1 sanitary piping and fittings.
1 brine tank.
1 brine pump.
1 tubular cooler (capacity 1,500 pounds an hour).
1 bottle filler.
1 turbine-brush bottle washer with tank, rinser, and steamer.

1 can wash sink with steam jet.
1 separator.
1 churn.
50 bottle cases.
20 10-gallon cans.
1 3-horsepower motor.
1 10-horsepower boiler.
Shafting, belting, pulleys, hangers piping, pipe, fittings, etc.
Chemical apparatus.

Estimated cost of the plant equipment, from $1,500 to $2,000.

*Principal equipment for a plant of from 300 to 500 gallons' capacity.*

1 platform scales.
1 300-gallon pasteurizing vat.
1 temperature recorder.
1 tubular cooler (capacity 4,000 pounds an hour.
1 brine tank.
1 brine pump.
1 sanitary milk pump.
Sanitary milk piping and fittings.
1 bottle filler.
1 bottle washer (turbine brush, rinser, and steamer).
1 can rinser and steamer.
1 separator.
1 churn and butterworker.
60 10-gallon cans.
150 milk-bottle cases.
1 dozen case trucks.
1 hand truck.
1 5-horsepower motor.
1 20-horsepower boiler.
Belting, shafting, pulleys, hangers, piping, pipe fittings, etc.
Steam and water hose with fittings.
Chemical apparatus.

Estimated cost, from $3.500 to $4,000.

*Principal equipment for a plant of from 500 to 800 gallons' capacity.*

1 2-valve dump and weigh can with strainer rack.
1 platform scales.
1 drip saver.
1 200-gallon receiving vat with cover and coils.
1 sanitary milk pump.
Pasteurizing and cooling outfit, 3,000 pounds an hour with automatic temperature control and recording thermometers.
Sanitary piping and fittings.
1 filler and capper.
1 hydraulic bottle washer; 2 compartments, power feed.
1 small wash sink with turbine brush.
1 wash sink with can rinser, steamer, and dryer.
1 separator.
1 40-gallon cream vat.
1 100-gallon jacketed vat.
1 churn and butterworker.
1 butter printer, ladles, and packer.
1 starter can for buttermilk.
100 10-gallon cans.
250 milk-bottle cases.
2 hand trucks.
Conveyer track.
1 5-ton ice machine.
1 brine tank with piping.
1 brine pump.
1 12-horsepower engine.
1 25-horsepower boiler with all necessary fittings and accessories.
Belting, shafting, pulleys, hangers, piping, pipe fittings, etc. (If live steam were used for pasteurizing, the boiler capacity should be doubled.)
1 special exhaust-steam water heater and storage tank (to supply hot water for pasteurizing and for washing purposes).
Chemical apparatus.
Bacteriological apparatus.

Estimated cost, from $8,000 to $10,000.

*Principal equipment for a plant of from 1,000 to 1,500 gallons' capacity.*

1 2-valve dump and weigh can.
1 platform scales.
1 drip saver.
1 sanitary milk pump.
1 300-gallon receiving vat with cover and coil.
Pasteurizing and cooling outfit with automatic temperature control and recording thermometers (capacity 4,000 pounds an hour).
1 clarifier (4,000 to 6,000 pounds an hour).
Sanitary milk piping and fittings.
1 supply tank to filler.
1 filler and capper.
1 small filler for buttermilk.
1 hydraulic bottle washer; 3 compartments, power feed.
1 small bottle washer with turbine brush.
1 can washer, rinser, steamer, and drier.
1 separator.
1 50-gallon cream vat.
1 150-gallon jacketed vat.
1 churn and butterworker.
Butter printer, ladles, and packer.
1 starter can.
200 10-gallon cans.
500 milk-bottle cases.
Trucks or conveyer tracks.
1 8-ton ice machine, with brine tank, piping, brine pump, etc.
1 20-horsepower engine.
Motors.
1 40-horsepower boiler with all necessary fittings and accessories (allowing 3 hours to pasteurize and cool 1,200 gallons milk).
Shafting, pulleys, belting, hangers, piping, pipe fittings, valves, etc. (If live steam were used for pasteurizing, the boiler capacity would have to be increased.)
1 special exhaust-steam water heater and storage tank to supply hot water for pasteurizing and for washing purposes.
Chemical apparatus.
Bacteriological apparatus.

Estimated cost, from $18,000 to $25,000.

*Principal equipment for a plant of from 2,500 to 4,000 gallons' capacity.*

1 2-valve dump and weigh can.
1 platform scales.
1 drip saver.
1 sanitary milk pump.
1 300-gallon receiving tank with cover and coil.
1 clarifier (8,000 pounds an hour capacity).
Pasteurizing and cooling outfit with automatic temperature regulator and recording thermometers (capacity 6,000 pounds an hour).
1 100-gallon vat pasteurizer.
Sanitary milk piping and fittings.
1 supply tank to filler.
2 fillers and cappers.
1 small filler for buttermilk, etc.
1 hydraulic bottle washer (4 compartments, power feed).
1 small bottle washer with turbine brush.
1 can washer, rinser, steamer, and drier.
1 forewarmer.
1 separator.
1 churn and butterworker.
Butter printer, ladles, and packers.
450 10-gallon cans.
1,500 milk-bottle cases.
Trucks and conveyer track.
1 starter can.
Motors.
1 300-gallon ripener.
1 300-gallon cheese vat.
2 drain racks.
1 buttermilk machine.
1 18-ton ice machine with brine tank, piping, and pump.
1 60-horsepower boiler, with all necessary accessories and fittings (allowing 3½ to 4 hours to pasteurize and cool 2,500 gallons of milk). Exhaust steam used. (If live steam were used for pasteurizing the boiler capacity would have to be increased.)

1 40-horsepower engine, with all necessary fittings and accessories.
Belting, shafting, pulleys, hangers, piping, fittings, valves, etc.
1 special 300-gallon exhaust-steam hot-water heater and storage tank, to supply hot water for pasteurizing and for washing purposes.
Chemical apparatus.
Bacteriological apparatus.

Estimated cost, from $30,000 to $40,000.

*Principal equipment of a plant of approximately 5,000 gallons' capacity.*

1 2-valve dump and weigh can.
1 platform scales.
1 drip saver.
2 clarifiers (12,000 pounds an hour combined capacity).
1 to 3 jacketed storage tanks (2,500 gallons each).
1 300-gallon receiving vat, with cover and agitator.
Pasteurizing and cooling equipment (10,000 pounds an hour) with automatic temperature regulator and recording thermometers.
1 small pasteurizer for cream.
1 small tubular cooler.
2 sanitary milk pumps.
Sanitary milk piping and fittings.
1 supply tank to fillers.
3 fillers and cappers.
1 small filler for buttermilk, etc.
1 hydraulic bottle washer (5 compartments, power feed).
1 small bottle washer with turbine brush.
1 can washer, rinser, steamer, and drier.
1 forewarmer.
1 separator (capacity 8,000 pounds an hour).
1 300-gallon jacketed vat.
1 rotary pump for skim milk.
1 churn and butterworker.
Butter printer, ladles, and packers.
900 10-gallon cans.
2,500 bottle cases.
Conveyer track.
Trucks.
1 starter can.
1 300-gallon ripener.
1 500-gallon standardizing and mixing vat.
1 300-gallon cheese vat.
2 drain racks.
1 buttermilk machine.
1 homogenizer.
1 30-ton ice machine with brine tank, piping, brine pump, etc.
2 125-horsepower boilers (one in reserve) with all necessary accessories and fittings. (5,000 gallons of milk to be pasteurized at the rate of 10,000 pounds an hour, in from 4 to 4½ hours.)
1 60-horsepower engine, or 70 horsepower motor, to run ice machine.
1 25-horsepower engine (exhaust steam used for pasteurizing and to heat water for washing).
Belting, shafting, pulleys, hangers, piping, pipe fittings, valves, etc.
1 special exhaust-steam water heater and storage tank to supply hot water for pasteurizing and for washing purposes.
Chemical apparatus.
Bacteriological apparatus.

Estimated cost, from $60,000 to $70,000.

*Chemical apparatus for average-sized milk plant.*

1 Babcock milk tester from 6 to 12 bottles—hand or steam operated.
3 dozen milk-test bottles, 8 per cent.
1 dozen cream-test bottles, 50 per cent.
2 pipettes, 17.6 c. c.
1 combined acid bottle and pipette.
1 lactometer (Quevenne).
1 burette, 50 c. c., graduated in tenths.
1 burette holder.
1 dozen beakers, 150 c. c.
1 dropping bottle, 30 c. c.
1 cream-test scale.
1 pipette, 10 c. c.
1 pipette, 25 c. c.
½ dozen skim-milk test bottles.

Approximate total cost, from $45 to $65.

*Chemicals for chemical analysis of milk and cream.*

Sulphuric acid, commercial, ½ gallon.
Phenolphthalein, 1 per cent solution, 100 c. c.
Sodium hydroxid, tenth normal, 1 liter.

*Bacteriological apparatus for milk plant.*

1 autoclave, medium size.
1 dry-sterilizing oven, gas stove, and kitchen oven.
1 incubator, 10 by 8 by 6 inches, inside dimensions.
1 balance, with weights to 5 kilos.
100 1 c. c. pipettes, graduated in tenths with an extra tenth above the 0 mark.
1 5 c. c. pipette.
1 10 c. c. pipette.
1 25 c. c. pipette.
1 100 c. c. pipette.
1 100 c. c. cylinder, graduated.
1 500 c. c. cylinder, graduated.
1 1,000 c. c. cylinder, graduated.
2 dozen Erlenmyer flasks, 1,000 c. c.
100 petri dishes, 100 by 10 m. m.
4 dozen glass bottles, 8 ounces, prescription or French square.
2 funnels, glass, 6-inch.
1 double boiler, ½ gallon.
1 thermometer (—10° to 100° C.).
1 thermometer (0° to 250° C. for dry sterilizer).
1 dozen glass stirring rods (assorted).
2 petri-dish holders, sheet iron, 50 dishes.
2 pipette boxes.
1 reading glass, 2½ magnifications, 4 inches.
1 counting plate.
1 tallying machine.
1 gas stove, single burner.
2 Bunsen burners.
12 feet gas tubing, ¼ inch.
2 wax pencils, blue or red.

*Chemicals and accessories for bacteriological examination.*

1 liter sodium hydroxid, tenth normal.
1 liter sodium hydroxid, normal.
1 liter hydrochloric acid, tenth normal.
1 liter hydrochloric acid, normal.
Absorbent cotton.
Nonabsorbent cotton.
Canton flannel for filtering.
Filter papers.
Peptone.

This bulletin and other department literature dealing with milk plants point out some of the more important economic and sanitary problems in the handling and distribution of milk. While all details can not be covered in these publications, they may serve to direct the attention of milk-plant operators or prospective operators to matters that might otherwise be overlooked.

## ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

March 25, 1925.

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